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DISCUSSION/REPLY

Reply to J.J. Muñoz-Perez et al. Comments on "Confirmation of beach accretion by grain-size trend analysis: Camposoto beach, Cádiz, SW Spain" by E. Poizot et al. (2013) Geo-Marine Letters 33(4)

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Abstract In a novel finding for a beach environment, Poizot et al. (2013) identified an FB+ trend (sediments becoming finer, better sorted and more positively skewed upshore) on a well-developed swash bar on the upper foreshore of the Camposoto beach of Cádiz in SW Spain. In their Discussion of that paper, Muñoz-Perez et al. (2014) provide some supporting arguments and also report grain-size, beach profile and other data from nearby beaches which differ from those of Poizot and colleagues for Camposoto beach, pointing out that a trend observed on one beach may not apply to a neighbouring beach. However, even though the absolute values differ, the overall trends actually do show the same general behaviour. In our Reply to their comments, we also address some difficulties in comparing granulometric datasets generated by different analytical techniques.

Preamble

Muñoz-Perez et al. (2014) discuss the GSTA (grain size trend analysis)-based findings of Poizot et al. (2013) who, for the first time in a beach environment, identified the existence of an FB+ trend (sediments becoming finer, better sorted and more positively skewed upshore) on a well-developed swash bar on the upper foreshore of Camposoto beach near Cádiz, SW Spain. While the validity of this unusual sediment trend case is not called into question by Muñoz-Perez and colleagues, they point out that this is in disagreement with some results obtained from other, nearby beaches. They then proceed to place our findings within a wider context with the aim of stimulating further research. We appreciate this opportunity of responding to the comments of Muñoz-Perez et al. (2014).

Response

Beach erosion rate

In the region of Cádiz along the Spanish Atlantic coast, the beach retreat rate of 1 m per year observed by Muñoz-Pérez and Enríquez (1998) as well as Anfuso et al. (2007) is more than twice that estimated by the VVAA (2007) team. The difference between the two rates can be explained by the inferred processes as well as the spatial scale on which the estimations are based. Muñoz-Perez et al. (2014) adopted the VVAA (2007) value as the actual rate of coastal erosion and retreat in the Cádiz study area. While this approach is not questioned in principle, it has to be taken into account that the results obtained by VVAA (2007) are based on climate-change scenarios, the uncertainties of which are evaluated using a set of climate models. These models apply mathematical parameterizations of processes which simultaneously affect the atmosphere, the ocean, the cryosphere (ice and snow), the biosphere and the soil. The large number of interactions between these compartments reflect the complexity of the Earth's climate system. Regional scenarios for Spain have been determined from all the available European climate models (PRUDENCE project financed by the European Commission's 5th Framework Programme). Even if the

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PRUDENCE database is one of the more accurate sources available for European climate change projections (spatial resolution of 50×50 km), the results are nevertheless derived from models and scenarios. As explained by Muñoz-Perez et al. (2014), models are prone to error because small variations in input parameters can induce dramatically different results, to the point of being contradictory. As a consequence, and in the context of an undisputed rise in sea level, three kinds of complementary approaches need to be considered: (1) an approach based on the work of the Intergovernmental Panel on Climate Change (IPCC) and the use of models targeted towards decision-makers and the public; (2) studies at a regional scale involving a synchronous characterization of the sedimentary dynamics at different locations; (3) a more local approach based on test locations monitored regularly throughout the year. Our study was conducted using this latter approach involving beach-scale observations.

As remarked by Muñoz-Perez et al. (2014), such studies are costly and time-consuming. It should therefore be of general interest to propose a more cost-effective method to the scientific community. The STA®/GSTA approach, along with the numerous studies undertaken in a large variety of environments, has amply demonstrated its usefulness, although its application to beach environments is still being debated (Masselink 1992; Masselink et al. 2008). Having been developed and mainly applied by sedimentologists, the GSTA method has thus far received little attention by coastal engineers. In recent years, some enhancements of the GSTA method have been proposed (e.g. Poizot et al. 2006; Poizot and Méar 2010) which also allow the investigation of sedimentological processes prevalent on beaches. A first result dealing with a beach in recovery was reported by Poizot et al. (2013).

Beach nourishment

To maintain its attractiveness to the tourism industry, Camposoto beach has been nourished with huge amounts of sand over the past few years. Muñoz-Perez et al. (2014) have updated the information concerning the total volume and cost of nourishment operations at Camposoto beach and it is, of course, important to operate with precise and up-to-date information when assessing the cost of environmental operations such as beach nourishment. In the case of the "older" data cited in Poizot et al. (2013), the conclusions nevertheless remain valid as they overall do reflect the physical and financial effort invested by national and local governmental authorities to support economic activities in the "sea-sun-sand" context.

Camposoto beach versus Victoria beach

Muñoz-Perez et al. (2014) highlight differences in the morphodynamic behaviour of the Camposoto and Victoria beaches. Although these beaches are located in close proximity, they should obviously not be compared without also pointing out fundamental differences such as the contouring conditions, exposure to wave energy, sediment grain size, and morphology.

Thus, Victoria beach is composed of two different sectors: a northern sector, which is protected by an extensive rock-shore platform exposed at low tide, and a southern sector, which does not exhibit such a platform. The two sectors display quite different morphologies, beach profile lengths, slope gradients and morphodynamic conditions, as already recognized by Bernabeu et al. (2002) and Avila-Serrano et al. (2010). The reef-protected northern sector exhibits shorter and steeper beach profiles and an intermediate morphodynamic state characterized by plunging breakers. The morphological response of such beaches to energy changes are best explained by the so-called "beach pivoting" mechanism (Nordstrom and Jackson 1992), which is usually focused on the high water level (HWL) or mean water level (MWL), or the so-called "parallel retreat" mechanism (Nordstrom and Jackson 1992) as observed by Anfuso et al. (2003) and Anfuso (2005). The unprotected southern sector, by contrast, displays a wide and smooth foreshore characterized by spilling breakers, where morphological changes can be best explained by the parallel retreat mechanism alone (Nordstrom and Jackson 1992; Anfuso et al. 2003; Anfuso 2005).

Camposoto beach commonly has a steep slope because of the coarser-grained sediment. Morphodynamically it occupies intermediate-reflective states characterized by substantial seasonal variations, morphological adjustments usually following the beach pivoting mechanism at MWL (Rangel 2013). In this sense, its behaviour is entirely different from that observed in the southern part of Victoria beach, but it is broadly similar to that observed in the reef-protected northern sector of that beach. The absence of a rock-shore platform and the steep slope of Camposoto beach due to the coarse grain size are thus major differences. The northern sector of Victoria beach, by contrast, shows an "artificial" profile with a relatively steep slope, which is only partly related to sediment grain size, but more essentially a function of wave transformation processes on the rock-shore platform (Bernabeu et al. 2002; Avila-Serrano et al. 2010).

Granulometric parameters

Minor differences have been pointed out by Muñoz-Perez et al. (2014) when comparing their granulometric data obtained on their Camposoto beach samples with the results of Poizot et al. (2013). In their Discussion article, Muñoz-Perez and colleagues provide some explanations for the small discrepancies, suggesting differences in the sampling procedure and analytical methodology or to unregistered differences in the beach morphology at the time of sampling. Of course, such arguments must be taken into account, but they are far from being the only points to consider.

One reason for the observed differences between statistical parameters may be the granulometric methodology. It is well known that the choice of granulometric measurement technique is one of the most important issues faced by sedimentologists, especially since the emergence of new automated methods (e.g. Sedigraph, settling tube, Coulter Counter and devices based on laser diffraction). Granulometric measurements of a sediment sample obtained with different techniques will inherently yield different results (see, for example, Sternberg and Creager 1961; Creager and Sternberg 1963; Sengupta and Veenstra 1968; Sanford and Swift 1971; Shideler 1976; Behrens 1978; Welch et al. 1979; Komar and Cui 1984; Stein 1985; Coates and Hulse 1985; Levant et al. 1985; McCave et al. 1986; Singer et al. 1988; Agrawal et al. 1991; Weber et al. 1991; Kench and McLean 1997; Buurman et al. 1997, 2001; Cramp et al. 1997; Bianchi et al. 1999; Olaisen et al. 2001; Dur et al. 2004; Scott-Jackson and Walkington 2005). Sieving and laser diffraction are currently the two main methods used for granulometric measurements. In the case of the sieving method, granulometric results are sensitive to sample mass, the conservation conditions and operator skill, to cite just a few of the factors involved. For the laser-based techniques, some of the factors impacting the results include the variability of algorithms used and the development of their performance based on increasing computer power, measurement settings (use and speed of the pump, use of ultrasound to disperse the sediment, optical theory and model taken into account). In both techniques, the particle-size determination can also be influenced by the composition of the sample, in particular the silt and organic matter contents. Numerous studies have compared these two techniques (cf. Citations above). While mathematical models are often proposed to transform one granulometric distribution into another, they are only valid for a particular sediment composition and the adopted protocol. Similar arguments apply when comparing any other methods.

Since Muñoz-Perez et al. (2014) do not give any information about the method used to obtain their granulometric data, it is highly problematical to compare the two datasets. The precise locations on the beach and the depths of sampling may explain some of the differences. It is common experience that, on some beaches, grain-size parameters can differ substantially between samples collected only a few metres apart. At the scale of beach studies, positioning systems used to determine sample locations must be highly accurate, i.e. less than 1 m uncertainty. Without this degree of accuracy, any comparison between samples can lead to doubtful results.

In our opinion, the main reason plausibly explaining the differences between the two granulometric datasets is that samples were obtained in different hydrodynamic situations. In the case of Poizot et al. (2013), sampling was carried out after a long period of relatively calm (low energy) weather, which may account for the significant difference between statistical parameters for the lower foreshore and the upper foreshore. Since Muñoz-Perez et al. (2014) give no information on whether their dataset was representative in the same context, this key issue remains unresolved.

Whatever the advocated reason for the discrepancies, the relative spatial evolution is still similar, i.e. the trend from lower to upper foreshore is the same, with the granulometry becoming finer, better sorted and more negatively skewed. In the GSTA approach, it is the relative change in statistical parameters from place to place which is important, not the absolute values of the parameters. In other words, from point A to point B, a change in mean grain size from 0.05 ϕ to 2.30 ϕ has the same significance as a change from 2.06 ϕ to 2.32 ϕ, i.e. the sediment becomes finer in both cases. Within the framework of GSTA, it is important to note that, contrary to what Muñoz-Perez et al. (2014) have intimated, the sedimentary trend case does not distinguish between positively and negatively skewed size distributions but rather between trends towards more positively (or less negatively) and more negatively (or less positively) skewed size distributions.

Sediment displacement speed

One of the reasons for applying the GSTA method to the Camposoto beach was the availability of previously collected independent data. Using more classical approaches (tracers, rods, etc.), Bellido et al. (2011) studied sediment movement at the beach scale. Poizot et al. (2013) compared those earlier data with the vector fields obtained through GSTA computation, with satisfactory results. The time elapsed between tracer dispersion and sampling) was about 9 h, and not 12.3 h as calculated by Muñoz-Perez et al. (2014). Considering the relationship between current velocity (0.056 m s^{-1}) and tracer velocity (0.0012 m s^{-1}), a coefficient of 0.021 is obtained, which is slightly different from the value of 0.016 calculated by Muñoz-Perez et al. (2014). In any case, the observed values are so close that they can be considered as being essentially identical to those obtained by Muñoz-Perez et al. (1999) on Regla beach located 40 km north of Camposoto beach.

Shape of beach profile

We fully agree with Muñoz-Perez et al. (2014) in stressing the importance of determining the precise environmental conditions under which the shape of a beach profile evolves. The dataset for Camposoto beach used in Poizot et al. (2013) leads to an overall convex beach profile. The environmental conditions which prevailed during data acquisition can be found in Bellido et al. (2011). The difference in beach profile shape highlighted by Muñoz-Perez et al. (2014) could be a consequence of different environmental conditions. Again, without any information about the hydrodynamic conditions prevailing before the sediment sampling campaign of Muñoz-Perez et al. (2014), it is not possible to discuss the reasons for the observed differences in the shape of the beach profile.

Conclusions

Muñoz-Perez et al. (2014) draw attention to some specific aspects of applying the GSTA method in our study of Camposoto beach. The lack of more detailed information concerning the environmental conditions, sampling procedure and analytical technique used in their study has prevented a more fruitful discussion of their comments. Nevertheless, taking their remarks into account, we consider the following procedures good practice in applying the GSTA method to the study of beaches:

1. granulometric datasets should reflect the environmental context of other parameterized datasets;
2. sample locations should be determined with an accuracy consistent with the scale of sedimentary processes;
3. the granulometric method applied along with the adopted analytical protocol should be identified and specified;
4. the latest improved version of the GSTA method should be used which, in particular, should incorporate the capability of analyzing all possible trend cases.

The interpretation of the results thus obtained is only meaningful within the specific environmental context of the study and after validation by other, complementary methodologies. Only when these conditions are satisfied can GSTA results be validated and confidently used on their own under strictly identical conditions.

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